AN OVERVIEW OF THE BLAST DESIGN FOR THE EXPLOSIVES DEVELOPMENT FACILITY

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ABSTRACT

Southwest Research Institute provided blast design consultation to Bernard Johnson Young Incorporated for the design of the Explosives Development Facility at Picatinny Arsenal, New Jersey. The facility makes use of the foundation of an existing building with a new steel frame building with metal panel siding. Additional new construction included two explosives test chambers, each rated for 15 pounds of explosives, explosives bays, and a 5-bay explosives magazine.

This paper provides an overview of the blast safety and explosion resistant design features of the facility. Siting was verified in accordance with AMCR 385-100 and DoD 6055.9. Blast resistant structural design was performed in accordance with TM5-1300. The explosives bays are partially vented cubicles with roofs, and are designed to stop primary and secondary fragments and to reduce wrap-around pressures to acceptable levels at adjacent areas. The main building structure is designed to resist these wrap-around loads. The test cells are designed to respond elastically to routine explosion tests. The test cells include a blast door, viewports, penetrations for ventilation and electrical, and fragmentation shielding. Finally, the side wall, back wall, and roof of the magazine were designed to withstand an internal explosion while deforming plastically. The front wall and door were designed to resist an explosion in an adjacent bay.

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1.0 INTRODUCTION

Southwest Research Institute (SwRI) and Bernard Johnson Young Incorporated (BJY) designed and prepared construction documents for the Explosives Development Facility at the U.S. Army Armament Research, Development and Engineering Center (ARDEC) at Picatinny Arsenal. BJY provided overall Architect-Engineer (A-E) services, while SwRI provided explosion safety and blast resistant design consultation. This project was performed under a contract with the New York District Corps of Engineers.

Construction of the Explosives Development Facility involved both rehabilitation and conversion of existing Building 3024, as well as new construction, to provide a research and development center devoted to explosives and insensitive munitions. This facility is capable of meeting ARDEC's mission with a modern, flexible, clean, environmentally-controlled laboratory space specially suited for sophisticated test and diagnostic equipment. In addition, the facility offers specialized safety features for testing and handling explosive items.

2.0 BUILDING LAYOUT

The layout of the Explosives Development Facility is shown in Figure 1. The main section of the building, stretching from east to west (plan), contains low hazard areas, offices, a control room for test cells, and other support areas. The outer shell of the building is steel frame with steel siding. This portion of the building is constructed over the existing slab from the original Building 3024.

Two reinforced concrete test chambers are housed in the new construction attached to the southwest corner of the main building. Tests will include firing series involving the interim qualification of new explosives, product improvement programs, detonation studies, and measurement of metal accelerating capabilities. The test chambers are enclosed in a room with reinforced concrete walls and a steel frame and steel deck roof. This area protects diagnostic equipment used during explosion tests.

The design included a series of eight reinforced concrete bays attached along the south wall of the main building. These bays will be used for explosives preparation, setback testing, ball drop testing, and explosive trains development. Finally, a five-bay explosives magazine is shown to the south of the building.

3.0 FACILITY SITING

SwRI conducted a review of the Explosives Development Facility to verify compliance with pertinent explosion safety criteria including AMCR 385-100 (Reference 1) and DoD 6055.9 (Reference 2). Prior to the A-E design phase, a Safety Site Plan (Reference 3) was prepared based on a preliminary facility layout. SwRI reviewed this document and concluded that the blast safety criteria above were met with the revised facility layout proposed by BJY and SwRI.

Adequate separation distance for blast overpressures is provided between adjacent facilities and the Explosives Development Facility by meeting pertinent inhabited building, public traffic route,

or intraline distances. Personnel in adjacent areas are also protected from fragments and debris through the use of barricades. Potential debris include the front wall and door of the magazine, the exterior equipment doors of the explosive bays, and the personnel door to the Instrument room. Each of these items will be stopped by the retaining walls to the south, southwest, and southeast of the facility. Analysis has shown that the metal panel roof sections of the building will not be thrown as debris in the event of an internal explosion. All other sections have been designed to resist blast loads to which they are subjected. Therefore, no debris will be thrown from the immediate area of the Explosives Development Facility.

Within the Explosives Development Facility, personnel protection exceeds the required limits. The explosives bays have been designed to partially contain the effects of an internal explosion. Blast loads will be vented through the exterior equipment doors, and personnel in the main building are protected by the walls and roof of the building which was designed to resist these vented loads. The walls of the laboratories inside the building have been designed to resist blast loads produced within each of the rooms. Blast resistant doors have been located to provide adequate protection. Finally, the magazine has been sited to meet the requirements of the barricaded intraline distance to the rest of the facility. The test chambers will completely contain the blast and fragments produced in an explosion test, and therefore, do not present explosion hazards to personnel in the facility or surrounding areas.

4.0 STRUCTURAL FEATURES

The structural design of the explosive bays, the magazine, and the main building was performed in accordance with the requirements of TM5-1300 (Reference 4). Since explosions in the test chambers will be repetitive, not one time, accidental events, they were designed using TM5-1300 for guidance along with the application of sound engineering principals. Based on discussions with personnel at Picatinny Arsenal, SwRI assumed that the explosive used in the facility was either RDX or HMX, both of which have a TNT equivalency of 1.149. A 1.2 safety factor was also applied to the charge weight to give the design explosive weight in terms of pounds of TNT.

4.1 Test Chambers

The test chambers were designed to contain blast and fragments produced by explosion tests of up to a Net Explosive Weight (NEW) of fifteen pounds. The charge was assumed to be centered in the room and three feet from the floor. The chambers are octagonal in plan with a sixteen foot span across the diameter from flat-to-flat. The octagonal shape was selected to allow the chamber to respond primarily in a hoop response mode, which is efficient in resisting the internal dynamic blast loads. A flat roof is provided with an internal height of fifteen feet.

Blast loads inside the chamber were calculated using the computer program BLASTX, Version 2.0 (Reference 5). This program has the ability to account for the shape of the structure. In addition, BLASTX predicts the total blast pressure history produced by internal explosions, including secondary reflections of the shock wave within the room. Use of a more accurate load history such as that calculated with BLASTX was deemed important for the design of the test chamber since the response of the test chamber must be elastic; therefore, there is a greater

possibility that individual pressure pulses may be in phase with the response of the structure, which could amplify the response over that predicted with a single triangular pulse.

The walls, roof, and floor of the test chambers are three feet thick. The walls are reinforced to resist hoop stresses, secondary flexural stresses (from localized bending in the short flat sections of the walls), diagonal tension and direct shear stresses, and direct tension stresses induced by the roof. Plan views of the walls are shown in Figures 2 and 3; Figure 4 shows a section through the walls. The roof was designed as a flat circular plate responding in a flexural mode. Typical reinforcement is provided for flexure, diagonal tension and direct shear, and direct tension induced by the walls. Typical roof reinforcement is shown in Figure 4.

A blast door was designed and placed in the east side of the chamber. The door, shown in Figure 5, is fabricated of six inch thick steel plate with six pins on each side. A stiffener is attached to the top and bottom of the door to limit deflections in this area, thus maintaining a seal. The door opens outward such that internal working space is not compromised, and to ensure that post-test debris does not jam the opening and closing of the door. The pins insert into a reaction bar to restrain the door when loaded internally. The reaction bar is welded to the door frame, which is anchored in the concrete wall.

Each chamber includes six viewports, placed in pairs as shown in Figures 3 and 6. The viewports were located to meet the diagnostic requirements of the facility users. Glass panes are held in place with a viewport cover shown in Figure 7. Existing test chambers at Picatinny Arsenal use two 2-3/32 inch thick quartz glass panes in each viewport; analysis of this configuration for the new loads has shown that they will also be adequate for the new chambers. When glass is not needed for a test, the panes are replaced by a 1-1/2 inch thick steel plate.

One cable penetration is provided for each chamber. The cable penetration is similar to the viewport penetration, except that a shroud is placed on the inside of the cable penetration to protect cable connectors from direct blast and fragment impacts. A 1-1/2 inch thick steel plate is placed at the opening, which can be drilled and tapped for electrical connectors.

One inch, two inch, and four inch thick fragment shields are placed on the inside surfaces of the walls, roof, and floor of the test chambers, as shown in Figures 2, 3, 4, and 6. These thicknesses were based on the experience of the users. Fragment shields are anchored to the walls and roof with bolts that extend through the section (see Figure 8). Anchors for the floor shields are embedded in the floor slab.

4.2 Explosives Bays

The explosives bays house operations utilizing larger quantities of explosives varying from five pounds NEW to twenty-five pounds NEW. The bays were designed in accordance with TM5-1300 to provide Category 3 protection between the bays and Category 1 protection to personnel inside the remainder of Building 3024. Unlike the test chambers, the bays were designed to undergo plastic deformations in the event of a one-time accidental explosion in one of the bays. Tests in these bays involving intentional detonations of small quantities of explosives (gram quantities) are contained

within blast shields.

In the event of an accidental explosion in a bay, the exterior door will be opened by the blast, causing shocks to propagate outside the bay, and allowing the explosion products to vent, reducing the quasi-static loads inside the bay. The programs SHOCK (Reference 6) and FRANG (Reference 7) were used to calculate the loads inside the bays. The walls and roofs of the bays were designed for these loads, and were constructed of two foot thick reinforced concrete (see Figure 9 for typical bay reinforcement). Reinforcement includes flexural steel, diagonals for direct shear, stirrups for diagonal tension shear, and tension steel for direct tension forces. Because stirrups were used, support rotations were limited to 4 degrees.

Blast doors are provided in the Explosives Trains Bay, the Set Back Bay, the Ball Drop Bay, and the Press Bay, allowing personnel direct passage between these bays and the Preparation/Small Scale Test Room. These blast doors were performance specification items, and are designed by the blast door manufacturer. All bays have equipment doors located on the south wall for personnel and equipment access. These doors will be blown open if an explosion occurs within the bay; however, these doors will resist loads vented from an adjacent bay, thus ensuring Category 3 protection is maintained.

4.3 Low Hazard Areas

The main building is primarily constructed of corrugated metal panels supported by a steel framing system. Exterior doors to occupied areas are either heavy duty hollow metal doors or special doors designed for the corresponding blast loads (performance specification items). Should an accidental explosion occur in one of the explosives bays, personnel inside the main building are provided Category 1 protection. This has been accomplished by designing the walls and roof sections to resist vented blast overpressures from the bays. TM5-1300 was used to provide criteria for designing these sections.

Explosives may be used in four of the rooms inside the main building. Up to 100 gram NEW may be in the Electrostatic Room, the Friction Impact Room or the Set Back Room. Up to 1 pound NEW may be in the Preparation/Small Scale Test Room or the Instrument Room. The walls of these rooms were designed to resist internal blast loads, thus providing Category 1 protection to personnel in adjacent areas. The walls of the Preparation/Small Scale Test Room are constructed of twelve inch thick reinforced and fully grouted masonry. The long walls were reinforced horizontally with a steel section. Rebar has been placed horizontally in the short walls to provide additional strength. The walls of the Electrostatic Room, Friction Impact Room, and the Set Back Room are similar except that eight inch thick masonry was used. Blast resistant doors are provided between these areas and all occupied areas. The areas around the doors have been reinforced to carry the reactions from the door response.

The walls of the Instrument room are twelve inch thick reinforced concrete, with rebar sized to resist an internal accidental explosion. In addition to providing blast protection, these walls protect personnel outside the Instrument Room from radiation hazards associated with a flash x-ray unit. Additional radiation shielding has been placed around the doors.

4.4 Magazine

The magazine consists of five 14 foot by 14 foot by 10 foot high bays with common walls between bays. The magazine was designed to provide Category 3 protection for 300 pounds NEW in each bay. Typical magazine reinforcement is shown in Figure 10.

Should an accidental explosion occur in one of the bays, the front wall of the bay will blow out. This wall (and door centered in the wall) was designed to resist the blast loads vented from an adjacent donor bay. The front wall is 12 inch thick reinforced concrete with a blast resistant door. Only flexural steel was required; stirrups and diagonals were not required as shear stresses were less than the concrete capacity. Debris from the wall and door will be stopped by the retaining wall south of the magazine, which acts as a barricade.

The remaining exterior walls are laced, 39 inch thick reinforced concrete sections. The roof is 45 inches thick and also is laced. These slabs were designed to resist an accidental internal explosion, thus preventing explosion propagation between adjacent bays and eliminating the potential for debris hazards to the north, east, and west. To reduce rebar congestion, stirrups, rather than lacing, were used in the dividing walls between the bays. This required a reduction in limiting support rotation from 12 degrees to 4 degrees.

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3. Stirrat, W.M., "Safety Site Plan for Explosives/Insensitive Munitions Facility", Revision 2, U.S. Army ARDEC, June 1992.

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5. Britt, J.R., "Enhancements of the BLASTX Code for Blast and Thermal Propagation in Protective Structures: BLASTX Version 2.0", Science Applications International Corporation, prepared for U.S.A.E. Waterways Experiment Station, Contract DACA39-92-C-0048, November 1992.

6. Anon., "SHOCK Users Manual", Version 1.0, Naval Civil Engineering Laboratory, Port Hueneme, CA, January 1988.

7. Wager, P., Connett, J., "FRANG User's Manual", Naval Civil Engineering Laboratory, Port Hueneme, CA, May 1989.

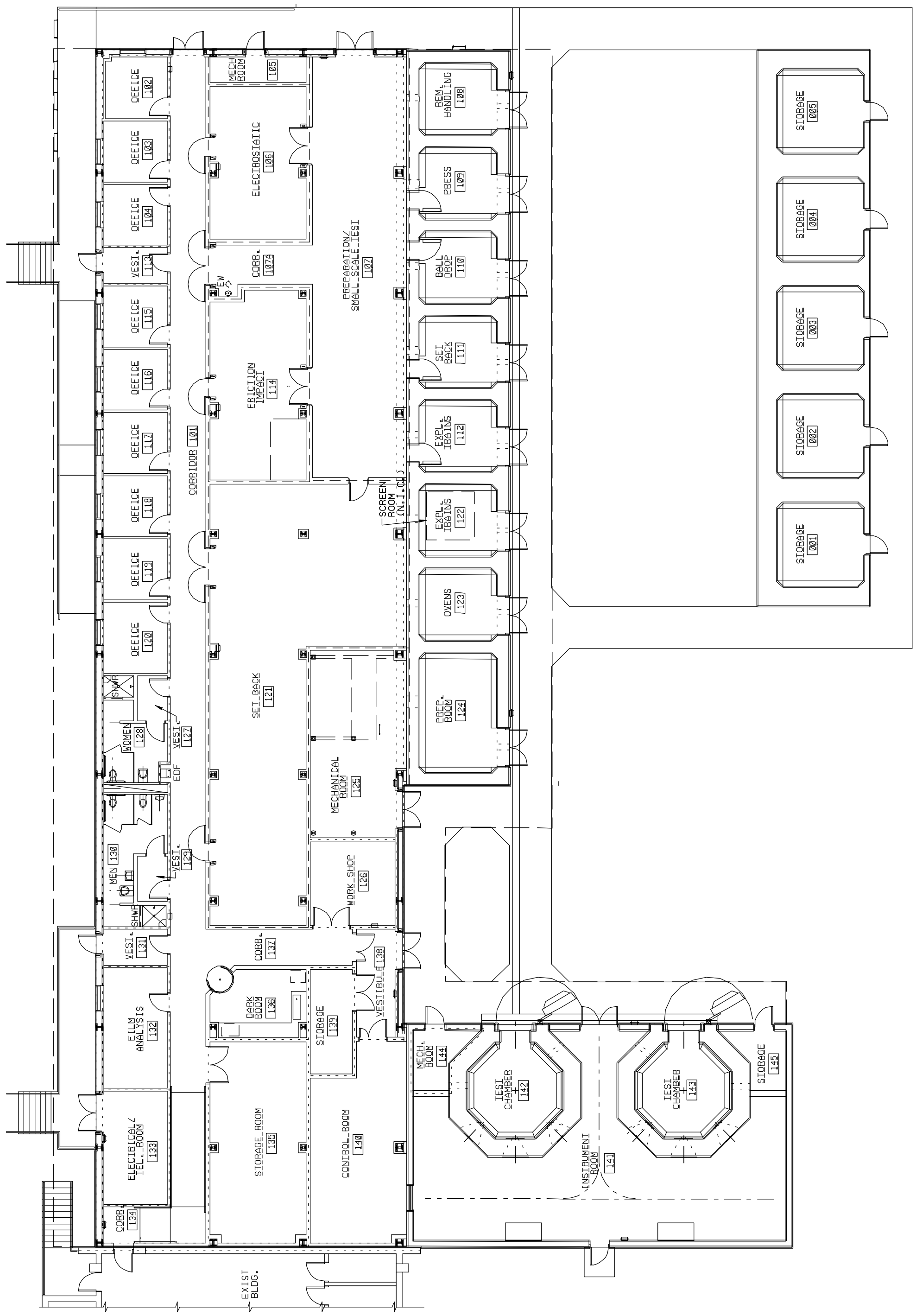

Figure 1. Layout of Explosives Development Facility

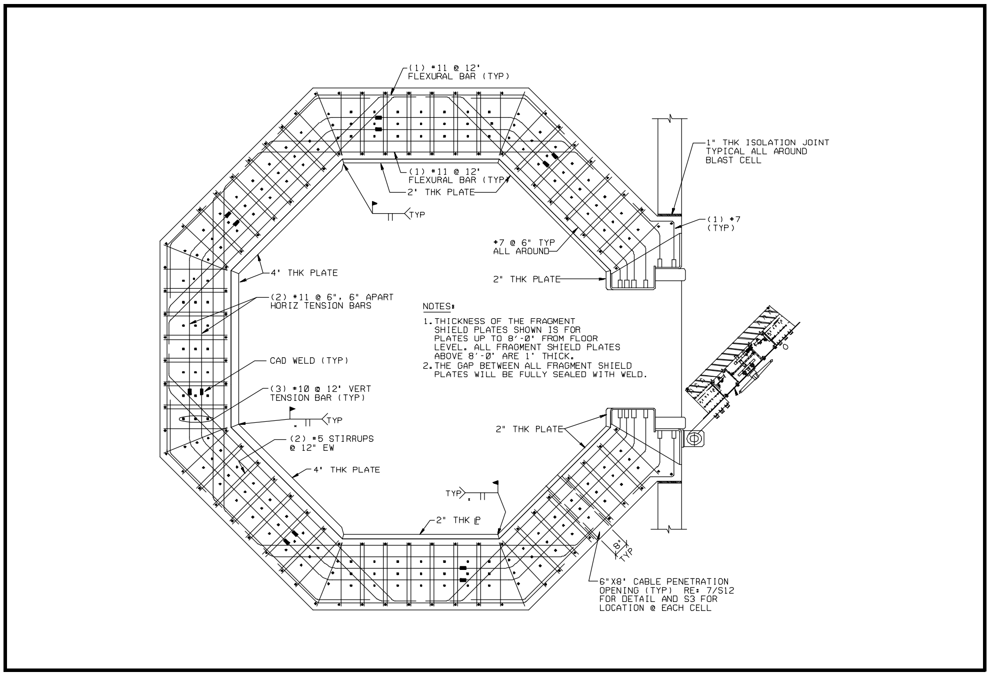

Figure 2. Test Chamber Plan

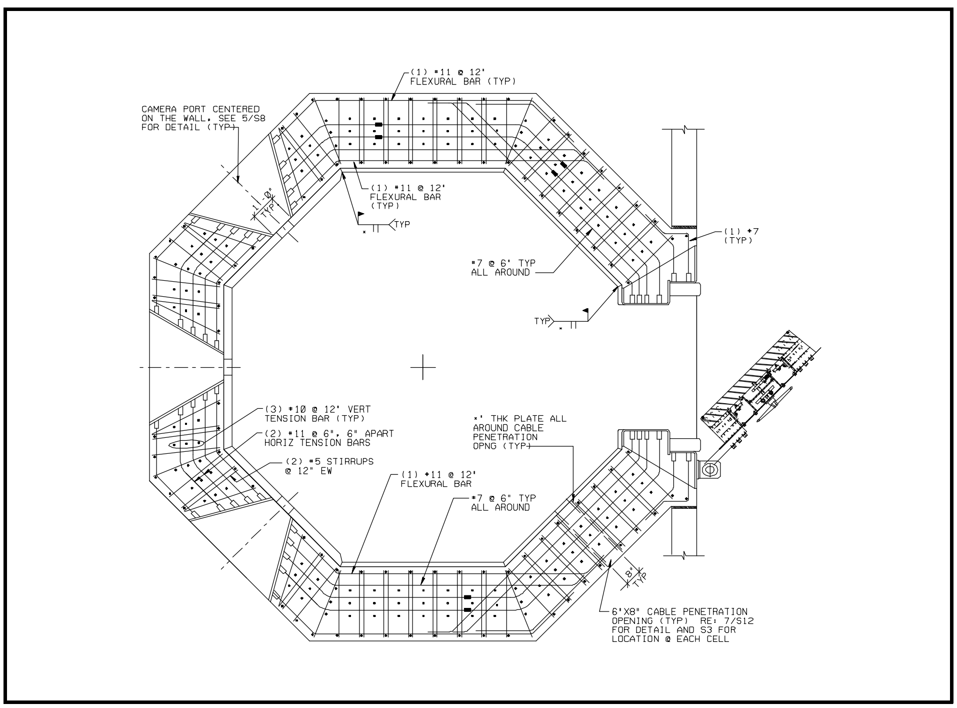

Figure 3. Test Chamber Plan (through viewports)

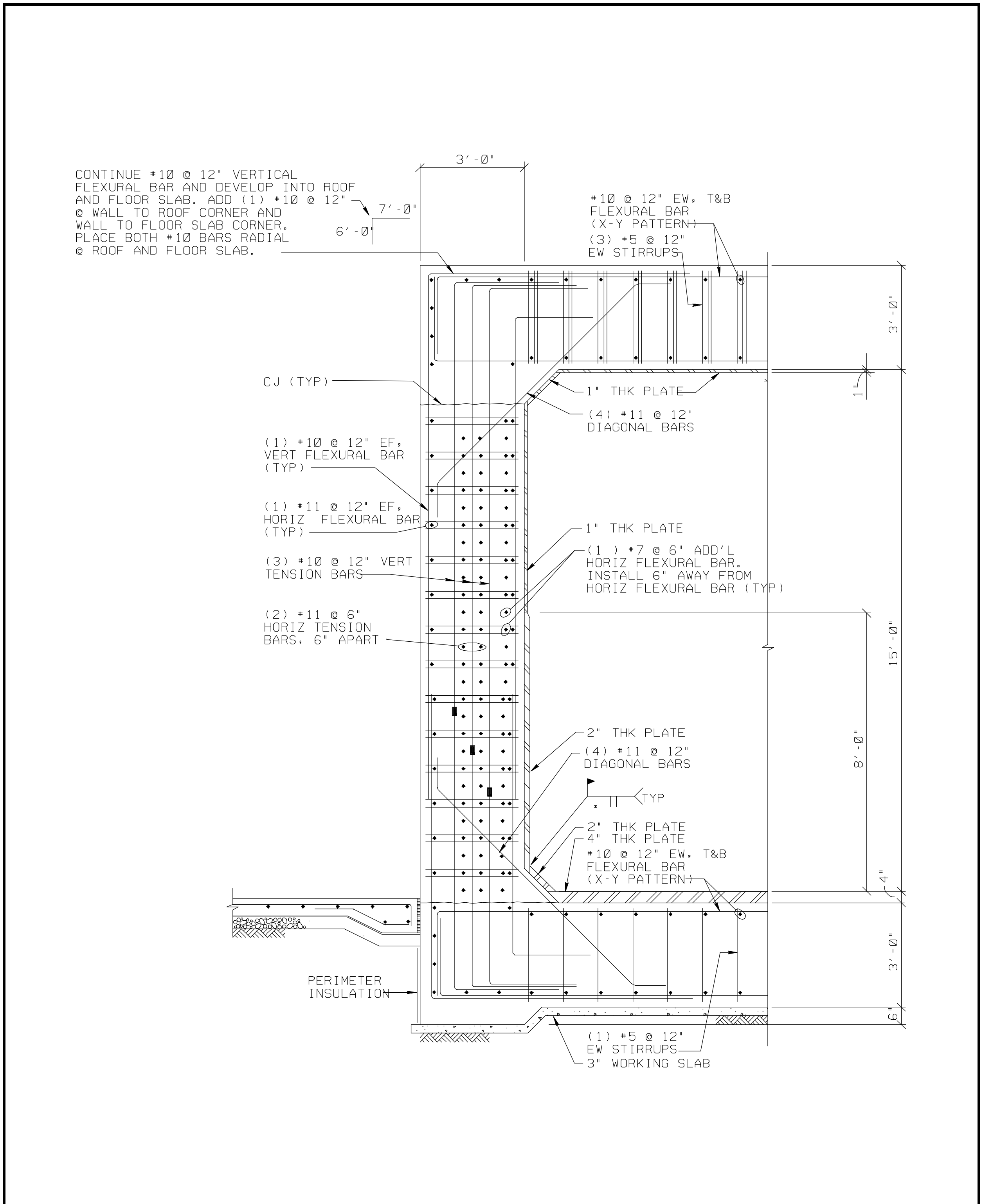

Figure 4. Test Chamber Section

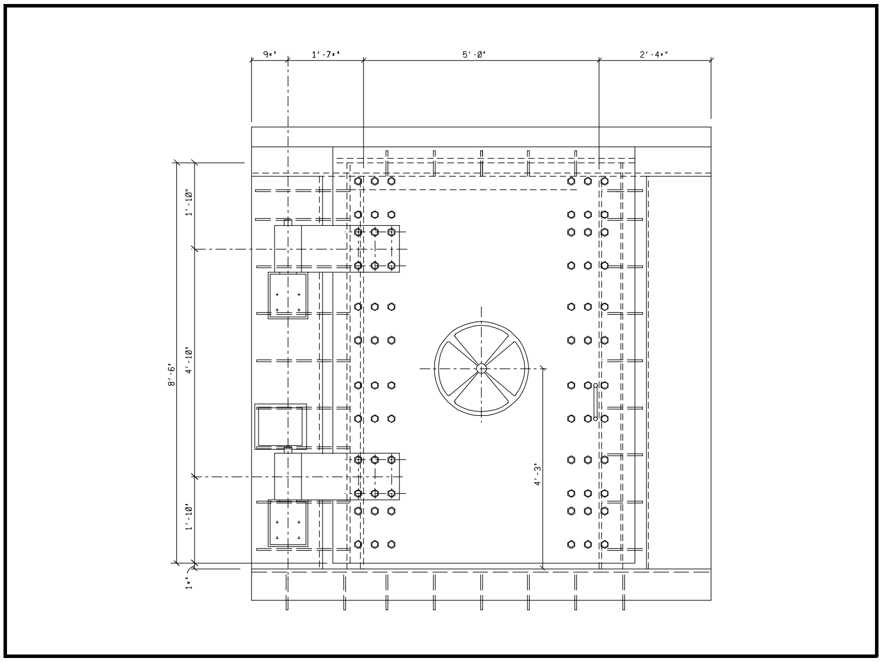

Figure 5a. Test Chamber Blast Door

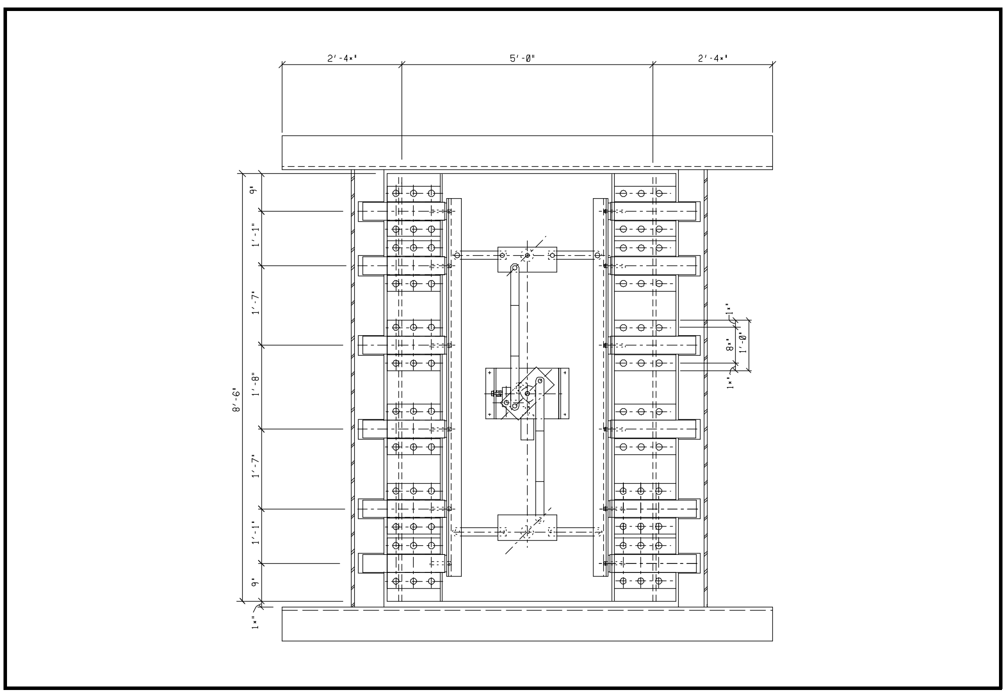

Figure 5b. Test Chamber Blast Door

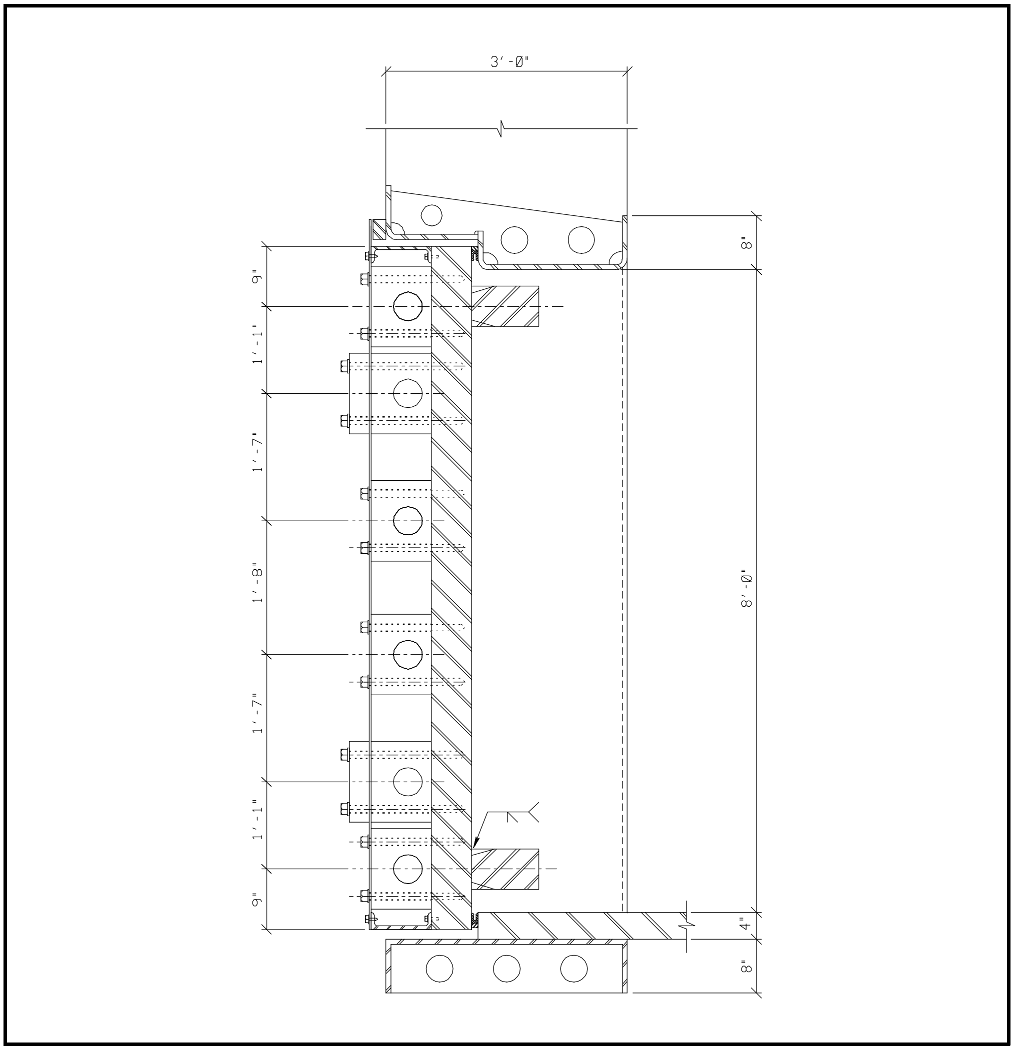

Figure 5c. Test Chamber Blast Door

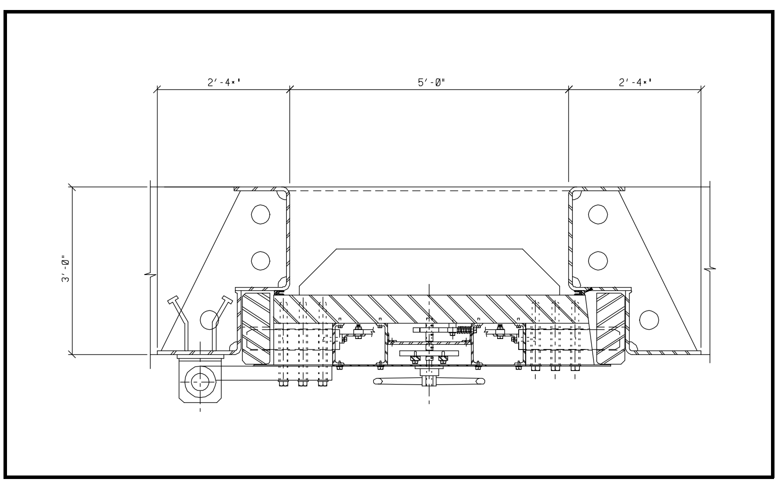

Figure 5d. Test Chamber Blast Door

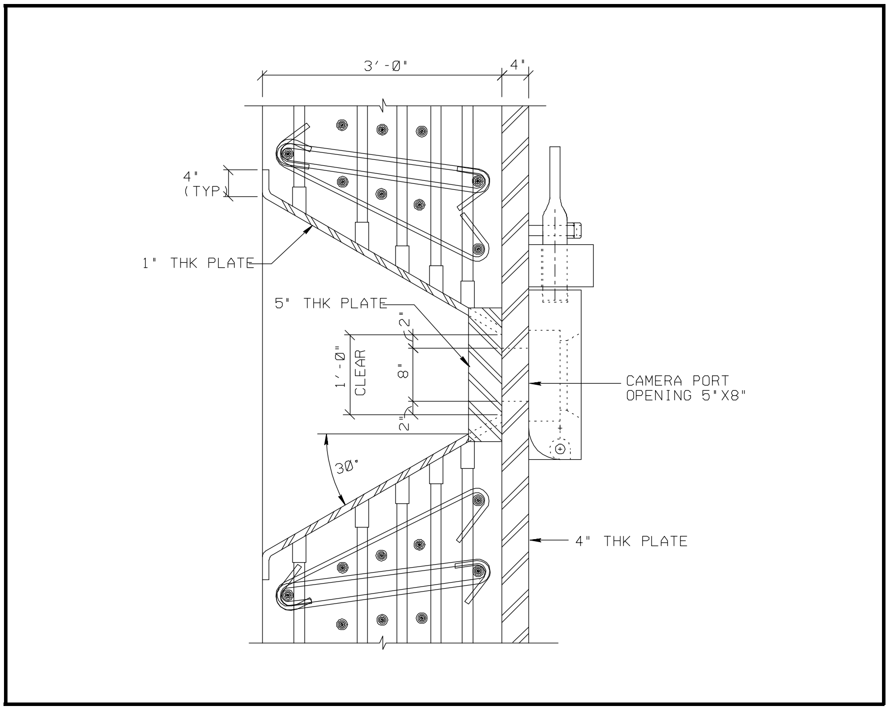

Figure 6a. Viewport Plan

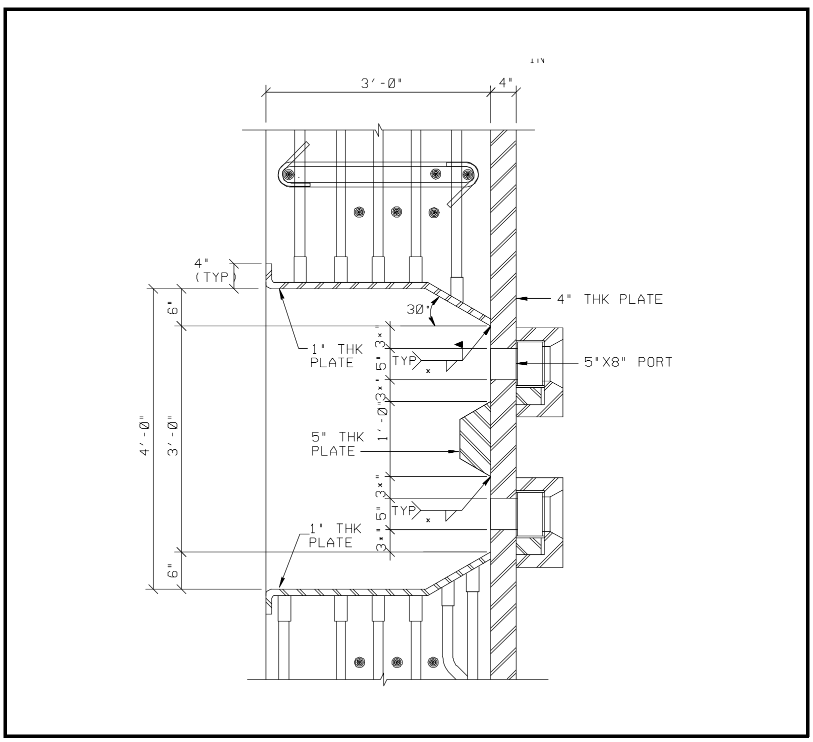

Figure 6b. Viewport Section

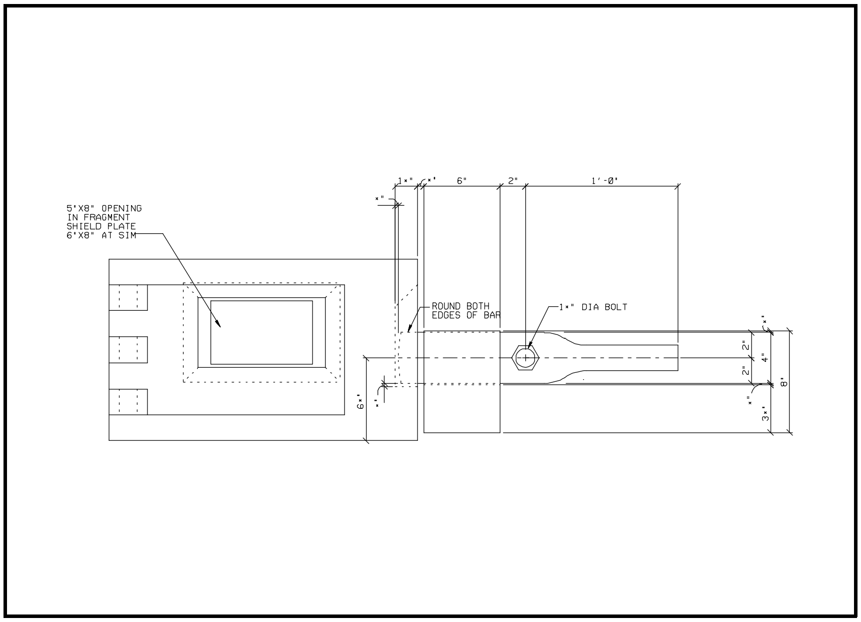

Figure 7a. Viewport Cover

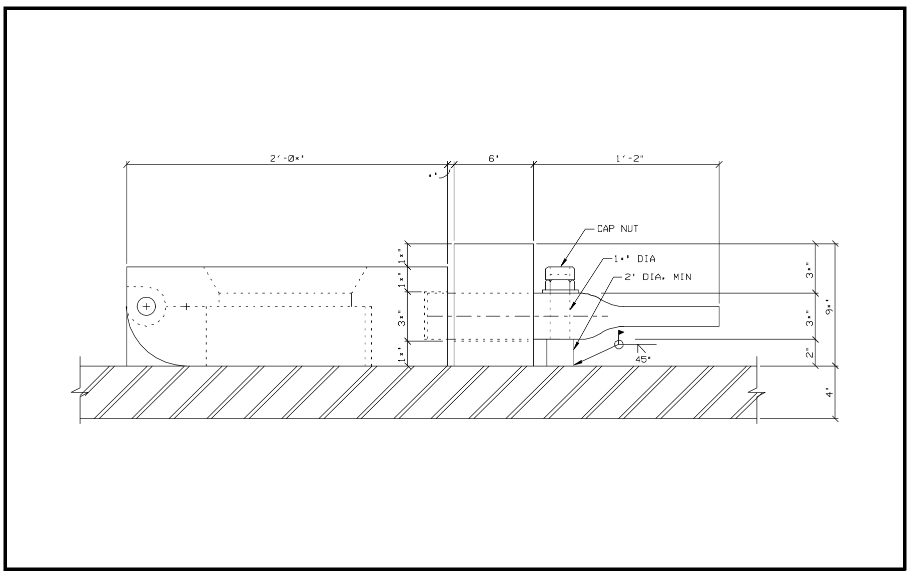

Figure 7b. Viewport Cover

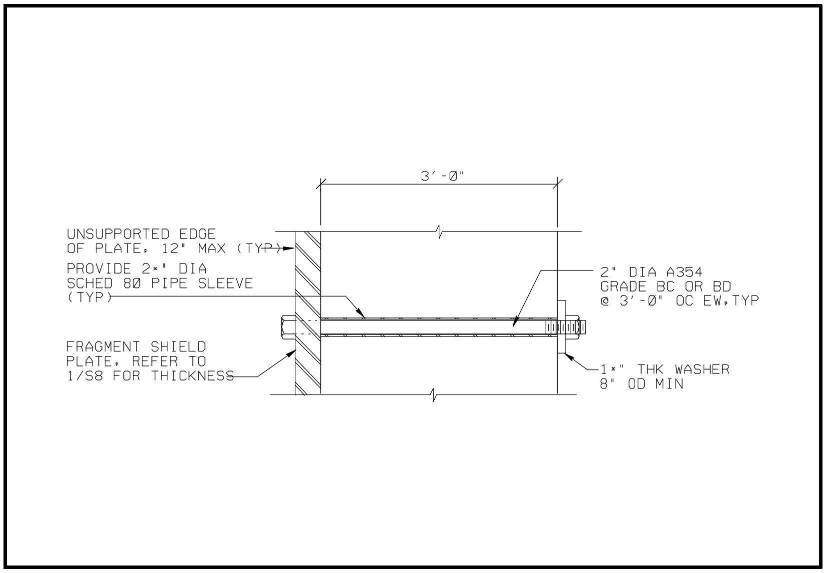

Figure 8a. Fragment Shield Anchorage

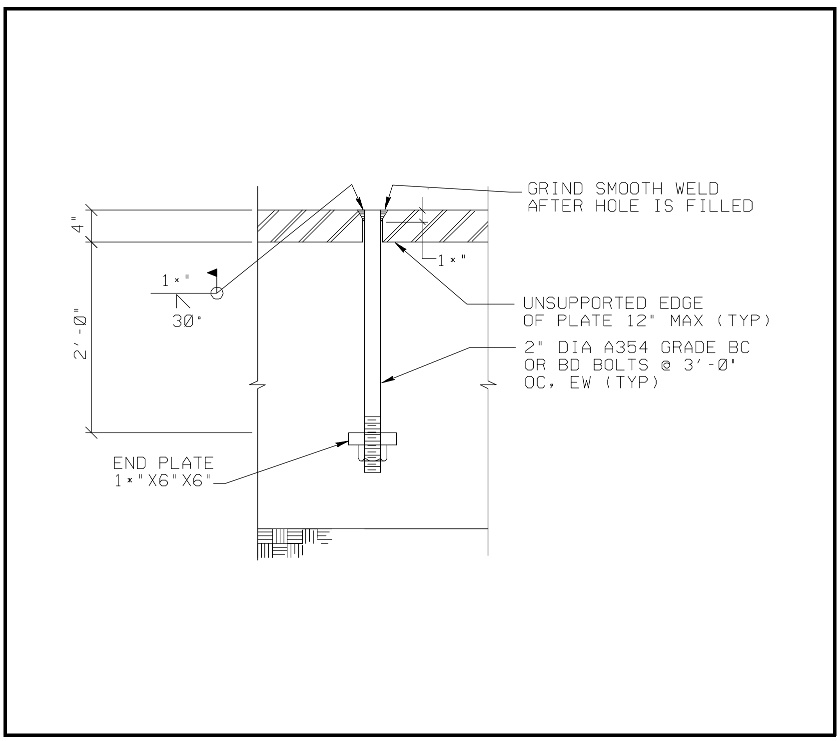

Figure 8b. Fragment Shield Anchorage

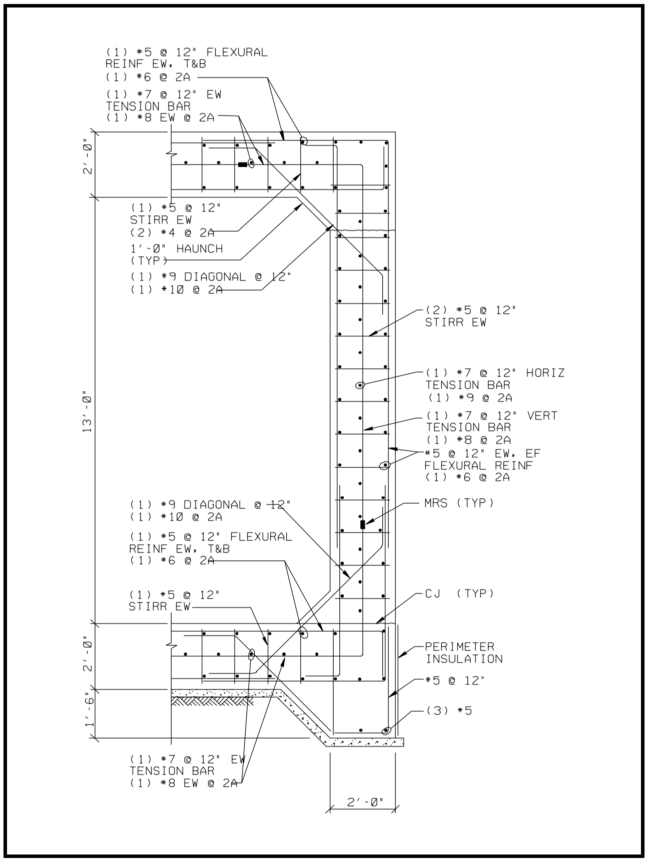

Figure 9a. Typical Bay Reinforcement

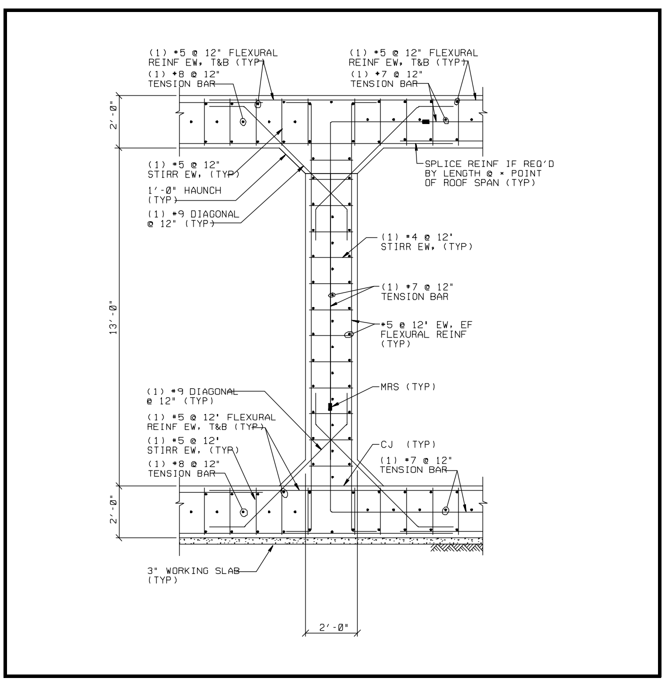

Figure 9b. Typical Bay Reinforcement

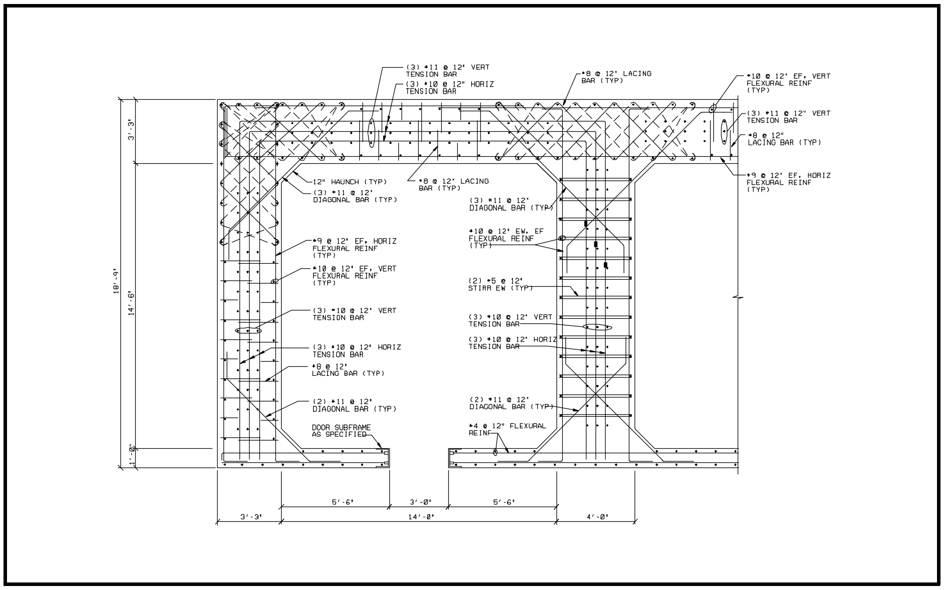

Figure 10a. Typical Magazine Reinforcement

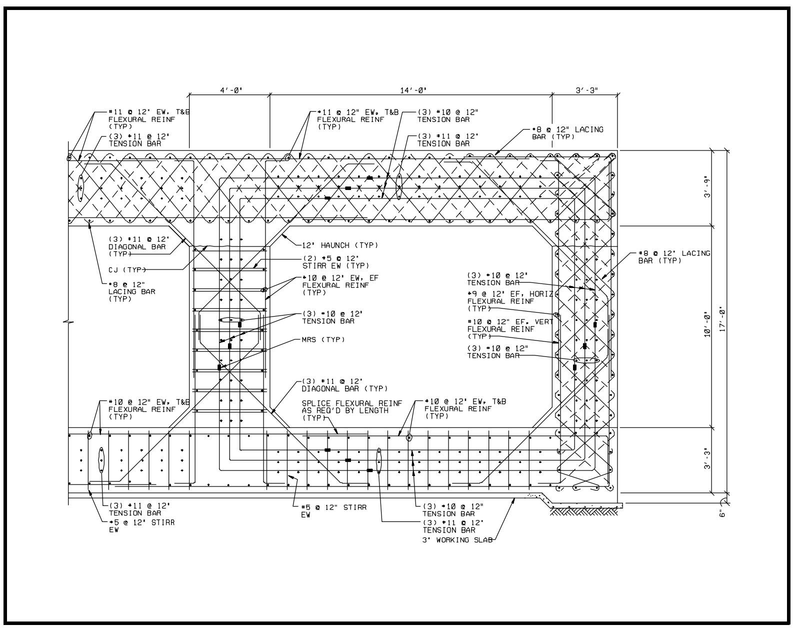

Figure 10b. Typical Magazine Reinforcement